REGULAR CONTINUATION-IN-PART

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LIGHTING APPARATUS WITH FLEXIBLE OLED AREA ILLUMINATION LIGHT SOURCE AND FIXTURE

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METHOD FOR PROVIDING REPLACEABLE LIGHT SOURCE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of copending, commonly assigned application U.S.S.N. 10/156,396 filed May 28, 2002, the disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates generally to a method for providing a replaceable light source and, in particular, to an efficient means to transport and vend replaceable light sources.

BACKGROUND OF THE INVENTION

Solid-state lighting devices made of light emitting diodes are increasingly useful for applications requiring robustness and long-life. For example, solid-state LEDs are found today in automotive applications. These devices are typically formed by combining multiple, small LED devices providing a point light source into a single module together with glass lenses suitably designed to control the light as is desired for a particular application (see, for example WO99/57945, published November 11, 1999). These multiple devices are expensive and complex to manufacture and integrate into single area illumination devices. Moreover, LED devices provide point sources of light that are not preferred for area illumination.

Electrically powered light sources are widely available for area illumination. Conventional illumination devices such as incandescent or fluorescent light bulbs are bulky, fragile, and problematic to handle and ship. Although the bulbs are filled with gas, the glass tubes are easily broken and occupy substantial space, especially in comparison to the actual light emitting area or material of the device. These light sources are typically made with either an evacuated glass bulb and an incandescent element (incandescent lighting) or a gas-filled glass bulb with a phosphor coating (fluorescent lighting). Both of these light

sources must be carefully packed, are very subject to breakage, and require significant volume for shipping.

Flat light sources are known in the art and can be shipped more efficiently than conventional sources. For example, US4626742 A issued 19861202 describes an electroluminescent device having a layout particularly suited for plug compatibility. The device includes a polymeric substrate having a first conductor fixed to the substrate. The first conductor is spaced inwardly from the edges of the substrate in a preselected pattern to form a first electrode. A luminescent coating covers a first portion of the first electrode leaving at least one edge of the first electrode uncovered. The luminescent coating extends across a second edge of the first conductor and onto the substrate. A pair of second conductors are situated adjacent to each other on the substrate at a preselected distance. One of the pair of the second conductors covers substantially the whole of the luminescent coating and extends across the second edge onto the substrate. The other of the pair of second conductors extends along the one edge of the first conductor and on into the substrate. Preferably the pair of second conductors are simultaneously deposited in position by a second screen printing.

US6565231 B1 entitled "OLED area illumination lighting apparatus" issued 20030520 discloses a solid-state area illumination lighting apparatus, including a plurality of light sources, each light source having, a substrate; an organic light emitting diode (OLED) layer deposited upon the substrate, the organic light emitting diode layer including first and second electrodes for providing electrical power to the OLED layer; an encapsulating cover covering the OLED layer; and first and second conductors located on the substrate and electrically connected to the first and second electrodes, and extending beyond the encapsulating cover for making electrical contact to the first and second electrodes by an external power source; and a lighting fixture for removably receiving and holding the plurality of light sources and having a plurality of first electrical contacts for making electrical connection to the first and second conductors of the light sources, and second electrical contacts for making electrical connection to an external power source.

Existing solid-state lighting elements may be planar and hence easy and cost-effective to ship but do not address the need for lighting elements that have a variety of conventional three-dimensional shapes as found, for example, in light bulbs for decorative lighting. As disclosed in the art, such flat-panel illuminators are not adapted to emit light in three dimensional configurations, for example, tabletop lamps and chandeliers. Multiple illuminators may be combined in a socket to create a 3-D effect but such an approach requires complex and costly sockets and the use of more than one illuminator. Such arrangements are not suitable for all lighting needs. It is also useful if a lighting device is readily and safely replaced by consumers at minimal cost.

There is a need therefore for an improved, replaceable OLED area illumination device having a simple construction using a single substrate, is compatible with the existing lighting infrastructure, is efficient to ship, and provides a variety of three-dimensional shapes.

SUMMARY OF THE INVENTION

In accordance with one embodiment of the invention, a method for providing a replaceable light source is described comprising the steps of: a) manufacturing a light source on a flexible substrate in a substantially two-dimensional configuration; b) shipping the light source in the two-dimensional configuration; and c) flexing and removably placing the light source in a curved three dimensional configuration within a lighting fixture.

ADVANTAGES

The present invention has the advantage of providing a lighting apparatus having a light source that can be manufactured, shipped, and stored efficiently in a planar configuration, thereby saving considerable storage space while providing a three-dimensional lighting source when in use. Another advantage is that the planar flexible light sources are not fragile and can be manufactured, packaged, shipped and stored in thin, unpadded packaging.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flow diagram illustrating the method of the present invention;

Fig. 2 is a perspective view of a flexible area illumination light source, including a detail of the layer structure, according to one embodiment of the present invention;

Fig. 3 is a perspective view of the flexible light source of Fig. 2 shown in a curved configuration;

Fig. 4 is a perspective view of a lighting fixture for holding the light source of Fig. 3 in its curved configuration;

Fig. 5 is a top view of the lighting fixture and light source showing clips for holding the light source in the curved configuration;

Fig. 6 is a perspective view of a light source and lighting fixture according to an alternative embodiment of the present invention;

Fig. 7 is a perspective view of an alternative embodiment of a light source useable according to the present invention;

Fig. 8 is a perspective view of a further alternative embodiment of a light source useable according to the present invention;

Fig. 9 is a perspective view of a lighting fixture holding a plurality of flexible light sources according to a further alternative embodiment of the present invention;

Fig. 10 is a perspective view of a light source held in a spiral configuration according to the present invention;

Fig. 11 is a perspective view of a light source held in a conical configuration according to the present invention;

Fig. 12 is a perspective view of a light source and lighting fixture having a standard base.

Fig. 13 is a perspective view of lighting apparatus according to the present invention including a light transmissive housing according to one embodiment of the present invention;

Fig. 14 is a perspective view of a stack of flexible light sources according to the present invention; and

Fig. 15 is a cross sectional view of an OLED light source as known in the prior art.

Fig. 16 is a perspective view of a plurality of light sources mounted on a rack according to one embodiment of the present invention.

Fig. 17 is a perspective view of a vending machine containing a plurality of light sources according to one embodiment of the present invention.

Fig. 18 is a side view of a roll of light sources according to one embodiment of the present invention.

Figs. 19a and 19b are perspective views of a portion of a roll of light sources connected in parallel and in series according to additional embodiments of the present invention.

Fig. 20 is a side view of an accordion fold of light sources according to one embodiment of the present invention.

It will be understood that the figures are not to scale since the individual layers are too thin and the thickness differences of various layers too great to permit depiction to scale.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 1, a method for providing a replaceable light source comprises the steps of: manufacturing **100** a light source on a flexible substrate in a substantially two-dimensional configuration; shipping **102** the light source in the two-dimensional configuration; and flexing **104** and removably placing **106** the light source in a curved three dimensional configuration within a lighting fixture.

Fig. 15 is a schematic diagram of a prior-art OLED light source **10** including an organic light emitting layer **12** disposed between two electrodes, e.g. a cathode **14** and an anode **16**. The organic light emitting layer **12** emits light upon application of a voltage from a power source **18** across the electrodes. The

OLED light source **10** typically includes a substrate **20** such as glass or plastic. It will be understood that the relative locations of the anode **16** and cathode **14** may be reversed with respect to the substrate. The term OLED light source refers to the combination of the organic light emitting layer **12**, the cathode **14**, the anode **16,** and other layers described below.

Referring to Fig. 2, a solid-state area illumination light source, includes a planar flexible substrate **20**, a flexible organic light emitting diode (OLED) layer **12** deposited on the flexible substrate, the organic light emitting diode layer including first and second electrodes **14** and **16** for providing electrical power to the OLED layer, a flexible encapsulating cover **30** covering the OLED layer, first and second conductors **24** and **26** electrically connected to the first and second electrodes, and extending beyond the encapsulating cover **30** for making electrical contact to the first and second electrodes **14** and **16** by an external power source, whereby the light source may be stored in a space saving planar configuration. The encapsulating cover may be a coated layer or an additional layer of material affixed over the OLED layers and sealed at the edges of the devices. Light may be emitted either through the substrate or the cover, or both, if they are transparent. The OLED layers themselves are continuous over the substrate to form a single contiguous light-emitting area. As shown in Fig. 3, the flexible substrate **20** can be curved into a three dimensional form and, as shown in Fig. 4, inserted into an aperture **36** in a lighting fixture **34** for removably receiving and holding the light source **10** in a curved three-dimensional configuration. The lighting fixture includes a support **38** having clips **39** for holding the light source in the curved configuration, and contacts **40** within the aperture **36** for providing electrical contact between the first and second conductors and an external power source.

The support **38** may be transparent. In one embodiment of the present invention, the flexible substrate **20** can define a tab portion **21** that may include an orientation feature such as step **28** to insure that the light source is inserted in the fixture in the correct orientation. The tab portion **21** can be inserted into the aperture **36** of the fixture **34** and the light source **10** shaped around the

support **38**. Alternatively, additional contacts may be included in the aperture or on either side of the flexible substrate using conductive vias to provide electrical contact with the conductors regardless of the orientation in which the tab is inserted (not shown).

The flexible substrate **20** may be fastened to the support **38** with, for example, an adhesive, hook loop fasteners, or a mechanical restraint such as a clip or detent. In applications where it is not required to emit light from both sides of the substrate, one or more of the substrate, cover, anode, or cathode may be opaque or reflective. The light source **10** may be physically inserted into or removed from the fixture by pushing or pulling the substrate **20** into or out of the aperture **36**.

Fig. 5 shows a top view of the support **38** with clips **39** for holding edges of the light source **10**. To install the light source **10** in fixture **34**, the tab portion **21** is first inserted into the aperture **36**. Next, the light source **10** is wrapped around the support **38** and the edges of the flexible light source **10** are inserted under clips **39** as shown by arrow A.

Referring to Fig. 6, in another embodiment, the flexible substrate **20** may define two tabs **21** and **22**. The first and second conductors **24** and **26** are each located on a respective tab portion and structured to fit into complementary apertures **36** and **36'** in a fixture **34**. The fixture **34** includes one or more fins **41** for supporting the flexible light source **10**.

Referring to Fig. 7 in a further embodiment, the substrate **20** does not define a physical protrusion but includes first and second conductors **24** and **26** located on an edge of the substrate **20**. Fig. 8 illustrates an alternative arrangement wherein the first and second conductors **24** and **26** are at opposite edges of the substrate **20**. In the embodiments shown in Figs 7 and 8, the apertures in the lighting fixture are wide enough to receive the entire edge of the substrate. Alternatively, the support can include clamps for holding two or more edges of the light source to bow the light source into a three-dimensional configuration, for example a cylindrical configuration. The contacts in the lighting fixture may be

located in the clamps. A wide variety of other configurations are readily designed, including rings or conical sections.

Referring to Fig. 9, an alternative fixture and support are shown wherein two light sources **10** are held in a common fixture **34**. The half cylinder configurations shown in Figs. 6 and 9 are useful, for example, for under-shelf lighting.

Fig. 10 illustrates another embodiment wherein the body of the light source **10** has an elongated rectangular shape and is held in a spiral configuration by the fixture **34**. Clips **39** are provided at both ends of the spiral for holding the light source. Fig. 11 shows an embodiment wherein the light source **10** is held in the shape of a cone by fixture **34**.

Referring to Fig. 4, the lighting fixture **34** can be adapted to connect the OLED light source **10** to an external power source (such as a standard household electrical grid, not shown). The fixture **34** may include power-conditioning circuitry **50** to convert the electrical power from the external power source to a form suitable for powering the OLED light source **10**. For example, the OLED light source **10** may require a rectified voltage with a particular waveform and magnitude; the power conditioning circuitry can provide the particular waveform using conventional power control circuitry. The particular waveform may periodically reverse bias the light emitting organic materials to prolong the life time of the OLED materials. The fixture may also include a switch (not shown) for controlling the power to the light source.

The brightness of the light source **10** may be controlled by varying the power provided to the OLED. In particular, pulse-width modulation schemes well known in the art may be employed (see for example, EP1094436A2, published April 25, 2001) and implemented by the power conditioning circuitry **50**. Alternatively, the amount of power provided to the light emitting area may be reduced, for example by reducing the voltage or limiting the current supplied to the OLED. A brightness control switch may be integrated into the socket, for example with variable resistance switch formed. The power source may be

standard 110 volt AC as found in North America, 220 volt AC as found in Europe, or other standard power configurations such as 24-, 12-, or 6-volt DC.

The OLED light source **10** can be provided as a standard element and fixtures **34** customized to markets with differing power systems. OLED light sources **10** may be provided with different shapes or other attributes useful in specific applications and may be employed with a common socket, thereby decreasing costs and improving usefulness of the lighting apparatus.

Referring to Fig. 12, the lighting fixture **34** may include a support portion **38** and a standard light bulb base **44** such as a US standard screw type lamp base as shown in Fig. 12, or a pin-type base (not shown). A wide variety of standard lamp bases are known in the prior art and may be used with the fixture of the present invention.

Referring to Fig. 13, a transparent or translucent screen or housing **52** may be provided around the OLED light source **10** to diffuse the light and provide additional physical protection and cosmetic appeal. The housing may take a variety of shapes, for example the shape of a standard light bulb.

Referring to Fig. 14, the flexible light sources **10** may be stacked and packed in a planar configuration for compact storage and shipment. This compact packing arrangement significantly reduces the packing volume necessary for traditional bulbs and provides a robust, sturdy means for storing, transporting, and stocking the lighting light sources **10**.

The present invention may be employed in a wide variety of conventional applications, for example in a table-top lamp, floor-lamp, ceiling lamp, or chandelier. The present invention may also be employed in portable illumination devices using DC power sources.

Because the light source is manufactured in a substantially two-dimensional configuration, methods known in the prior art for depositing materials on two-dimensional substrates may be employed, thereby reducing the cost of manufacturing the light source 10. Once the light source 10 is manufactured, a plurality of light sources may be packaged in a substantially flat configuration, as shown in Fig. 14, thereby reducing costs and breakage of the light sources. If the

light sources are shipped to a retailer, the light sources may be displayed for purchase, for example by mounting a plurality of light sources either within a single package or separately on a rack. Referring to Fig. 16, packages **60** containing a plurality of light sources **10** is mounted upon a rack **62** with pegs **64** projecting through a corresponding hole in the packages **60**. A customer may then purchase a package and convey it to his or her home where the package is opened, one or more light sources removed, flexed, and mounted in a three dimensional configuration as illustrated in Figs. 3- 6 and Figs. 9-13. Preferably, the customer will flex the light source by the edge to avoid marking the surface of the light source with dirt. It is also possible for the package shown in Fig. 16 to be opened in a retail location and individual light sources removed and purchased by a customer. Hence, a plurality of light sources in a flat configuration within a dispenser may be adapted to dispense one light source at a time

The light source of the present invention may also be sold in a vending machine in packages of one or more. Referring to Fig. 17, a vending machine **66** includes means for accepting money such as slot **68** and a supply of light source packages **60**. Since the packaged light sources of the present invention are robust and easily shipped in a compact configuration, they are readily transported by surface mail and can be sold through mail order.

The light source of the present invention may also be sold together with a variety of other light-related products to induce consumer demand. For example, light sources may be provided at no cost with a complementary socket or lighting fixture such as a desk lamp or light fixture designed to provide power to the light source to induce sales of the light-related products. Alternatively, sockets, lamps, and fixtures may be provided at no cost to induce the sale of one or more light sources. These sales techniques may be extended to include refunds for prior light source purchases when a complementary product is purchased (for example sockets or lamps), discounts on the price of a new light source in exchange for a used or burned out light source. Light sources may also be recycled and deposits paid by consumers that are refunded upon return of a light source to encourage recycling.

Non-emissive portions of a light source, or the packaging of a light source may have advertising placed on a non-emissive portion of the light source. Package advertising may be provided before or after shipment to a retailer or wholesaler for sale to a consumer.

Consumers may also test the light sources before purchasing by providing means to access the electrodes of the light source and apply power to the light source, thereby establishing the performance of the light source before purchase and/or while the light source is still in a package.

The description of the shipping method in the present invention has been addressed to shipping light sources in a substantially two-dimensional configuration. However, since the substrates of these light sources are, in fact, flexible, they can be shipped in a variety of configurations. As discussed above and illustrated in Figs. 14 and 16, a plurality of light sources may be packaged in a flat package. Alternatively, referring to Fig. 18, the light sources **10** may be rolled up in a cylindrical roll **70** having a minimum diameter corresponding to the flexibility of the light sources. In this arrangement, the light source **10** is substantially, but not completely, flat. This configuration then forms a hollow cylinder that is not as dense as a flat pack but has the advantage that light sources may be dispensed individually from the roll by sequentially detaching the light sources from the outer end of the roll. The light sources may be sequentially fastened to each other through their individual packaging (e.g., cardboard backing **72**) or by other fastening means such as the flexible substrate, with or without perforations **74** to aid detachment.

In such a cylindrically rolled configuration, the light sources may also be detached in groups, for example three linked light sources may be detached so that all three light sources remain connected. Referring to Figs. 19a and 19b, it is also possible to supply the packaging in such a way that the light sources are also electrically connected in parallel (Fig. 19a) or in series (Fig. 19b), using conventional conductors **76** fastened to or embedded in the light source packaging. In this arrangement, a light fixture can provide power to groups of individual light

sources, obviating the need to individually mount the light sources and reducing the need to flex individual light sources.

Referring to Fig. 20, in an alternative configuration, the light sources **10** may be fastened sequentially on a backing **72** as described above for a cylindrical roll but configured in an accordion folded stack **80** so that the light sources are compactly stored flat but also enabling electrical connections between sequential light sources and also enabling sequential dispensing and detaching in groups of one or more light sources at a time.

In a preferred embodiment, the Organic Light Emitting Diode layers (OLED layers) are composed of small molecule OLEDs as disclosed in but not limited to US Patent 4,769,292, issued September 6, 1988 to Tang et al., and US Patent 5,061,569, issued October 29, 1991 to VanSlyke et al. Alternatively, polymeric or oligomeric OLED materials may be employed.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

10	OLED light source
12	organic light emitting layer
14	cathode
16	anode
18	power source
20	substrate
21	tab portion of substrate
22	tab portion of substrate
30	encapsulating cover
24	first conductor
26	second conductor
28	step
34	lighting fixture
36	aperture
36'	aperture
38	support
39	clip
40	contact
41	light source support fin
44	standard lamp base
50	power conditioning circuitry
52	light transmissive housing
60	packages
62	rack
64	pegs
66	vending machine
68	slot
70	cylindrical roll
72	backing
74	perforations
76	conductors
80	accordion folded stack